NEGATIVE WTI PRICE: WHAT REALLY HAPPENED AND WHAT CAN WE LEARN?

LINGJIE MA

ABSTRACT. The price of WTI futures contracts fell into the negative on April 20, 2020. In this paper, I investigate underlying factors that contributed to the negative price and propose rule changes. Regarding the causes, first, due to the COVID-19 pandemic and an oil price war, an oil oversupply and storage shortage put huge downward pressure on oil prices; second, CME group made policy changes in early April allowing negative prices; third, heterogeneous trading activities of retail investors and speculators contributed to the negative price on April 20. To improve market efficiency and fairness for market participants, I propose rule changes, such as more advance notice for market rule changes, robust alternatives for settlement price construction, and appropriate limit on TAS contracts.

1. INTRODUCTION

On April 20, 2020, the price of West Texas Intermediate (WTI) contract (May 2020) went into the negative with the settlement price of -$37.65 (Fig. 1.1). This is the first time in history that the price of oil has fallen into the negative. How did this really happen? How can the price of oil be negative?

FIGURE 1.1. U.S. oil prices reached below zero for the first time in history on April 20, 2020. Data source: Reuters

In this paper, I investigate underlying factors that contributed to the negative price and propose some rule changes for the potential enhancement of market efficiency and fairness.[1] Regarding the causes, the big picture was the COVID-19 pandemic declared on March 11, 2020, which caused a sharp drop in demand for crude oil, while oil production

Lingjie Ma: Department of Finance, the University of Illinois at Chicago; Email: lingma1@uic.edu; Phone: 847-977-8728. I thank Richard Co, Ilia Bouchouev, two referees, and seminar participants at the University of Illinois at Chicago and Johns Hopkins University for their constructive comments.

[1]The paper investigates fundamental conditions as well as rule and market changes over a long period prior to April 20 and special characteristics of trading activities on April 20, 2020.

remained steady, creating a glut. In early April 2020, CME changed the rule allowing negative prices. The macroeconomic situation and policy provisions made negative prices possible. That possibility was then realized as a result of the specific situation on April 20, the penultimate day for the 2020 May WTI contract: retail investors, including the ones from Bank of China, held a large number of long positions of trade-at-settlement (TAS) contracts; speculators such as Vega Capital bought TAS shares early in the day and then netted positions close to the market settlement time, placing huge downward pressure on the price of WTI which dropped to negative.

While there are many studies on the price of oil, there is very little research on the negative price of oil. One reason is that it just happened for the first time a year ago. Nevertheless, there have been a few studies about the negative price. Bouchouev (2021) argues that while a lack of storage was a potential catalyst for negative prices, storage costs alone could not have moved the market down by $57 per barrel and back within a few hours. The negative price also drew investigations by US regulatory agencies, such as the Commodity Futures Trading Commission (CFTC). The CFTC published an Interim Staff Report on Nov 23, 2020, describing the macroeconomic situation and some trading activities around April 20, but did not specify exactly how the negative price occurred or what actions regulators should take (CFTC, 2020).[2]

From a theoretical perspective, many studies of the oil market focus specifically on speculators' impacts on prices, such as through TAS contracts. Jarrow (1992) discusses necessary conditions for making profits from trade-based manipulation and finds that purchases and sales have asymmetric price responses. Allen and Gorton (1992) point out that purchases are more likely to be driven by private information than sales, so purchases will have a larger price impact than sales. Kumar and Seppi (1992) analyze a model with private information showing that early transactions have no impacts on price, while dumping in a later period (based on private information) will generate manipulated profits. In a recent study, Pirrong (2019) analyzes TAS contracts using a manipulation model and shows that there are significant opportunities for TAS traders to manipulate prices, a finding that is confirmed by the case study of Optiver. Linking information asymmetry with information access cost, Frino et al. (2020) examine the impact of fee changes of real-time data on WTI, they find that retail investors have less access to information than experienced speculators.

Given the findings of these theoretical and empirical studies, I argue that we need not only to understand what exactly happened around April 20, 2020 but also learn from the event to improve market fairness and efficiency.[3] I present a holistic explanation for the negative price event at three interconnected levels: fundamental, policy, and trading. Moreover, I provide policy recommendations: first, market participants should receive enough advance notice of structural changes that they can prepare and provide feedback before the changes are implemented; second, settlement pricing can be improved, for example, by providing more time around expiration days, constructing prices in a robust way against outliers, and applying conditions of market liquidity; third, limits should be

[2]The report has been criticized by the organization's own commissioner for a lack of critical evidence and policy proposals (CFTC, 2021).

[3]Market fairness can be regarded as a brake upon self interest, ensuring that the market being impartial and equitable.

imposed on TAS orders, and rules such as conditioning on liquidity measurements should be applied. To the best of my knowledge, there has been no study yet that considers these factors together to analyze the causes of the negative price event and propose policy recommendations. This study addresses this gap.

The rest of the paper is organized as follows. Section 2 presents the fundamental situation surrounding the negative price event. Section 3 discusses trading policy and rules for WTI contracts. Section 4 describes what exactly happened in terms of trading activity on April 20. Section 5 proposes policy enhancements. Section 6 summarizes and concludes.

2. Fundamental situation

In this section, I characterize the fundamental situation in early 2020 that contributed to the historically low oil prices. Because of the COVID-19 pandemic, demand for oil plunged in March and April 2020. Meanwhile, oil production increased due to the price war between Russia and Saudi Arabia, creating a glut. This situation of unprecedented oil oversupply created two issues: a surge in retail oil investors attracted by very low oil prices and a storage shortage.

2.1. **Oil demand plunged due to the COVID-19 pandemic.**

During the pandemic in 2020, as many people stayed and worked from home, they drove and flew less. The greatest impacts of this were on the service industry and oil demand. Note that in the US, automobile and air travel account for about 60% of oil consumption, hence the 30% over supply of crude oil in the US in April 2020. As a result, oil was affected the most of all commodities, while necessary goods such as food, and other commodities, such as gas and electricity, were much less affected by the pandemic and economic lockdown. Industrial material goods, such as copper, steel, and lumber, were also not affected as much as oil.[4]

As a proxy, we use the world liquid fuel production and consumption to measure the imbalance between supply and demand in the crude oil market. Fig. 2.1 presents monthly values from January 2019 to August 2020, where the dashed line is for April 2020. On March 11, 2020, the World Health Organization (WHO) declared the novel coronavirus (COVID-19) outbreak a global pandemic. We see clearly that before the pandemic crisis, the world liquid fuel market was in a well-balanced range. However, beginning from March 2020, demand plunged very quickly from 100 million barrels per day (mbd) to 90 mbd and reached its lowest point of 80 mbd in April 2020.

To see in detail how different end usages of oil contributed to the decrease in demand, I decompose total petroleum consumption into different usages. Using the US as an example, Table 2.1 shows that of the total consumption decrease of 5.64 mbd from April 2019 to April 2020, motor vehicle fuel demand comprised 3.96 mbd, jet fuel 1.07 mbd, and distillate fuel 0.61 mbd. These represented drops of 38%, 61%, and 15%, respectively. Note that from 1997 to 2020, the US average consumption of motor vehicle fuel was 9.44 mbd and jet fuel was 1.56 mbd. In April 2020, US motor vehicle gas consumption was 6.38 mbd and jet fuel consumption was 0.69 mbd. Clearly, people drove and flew less in April 2020, both consumptions reaching historical lows since the 1990s.

[4]I thank a referee who addressed this point.

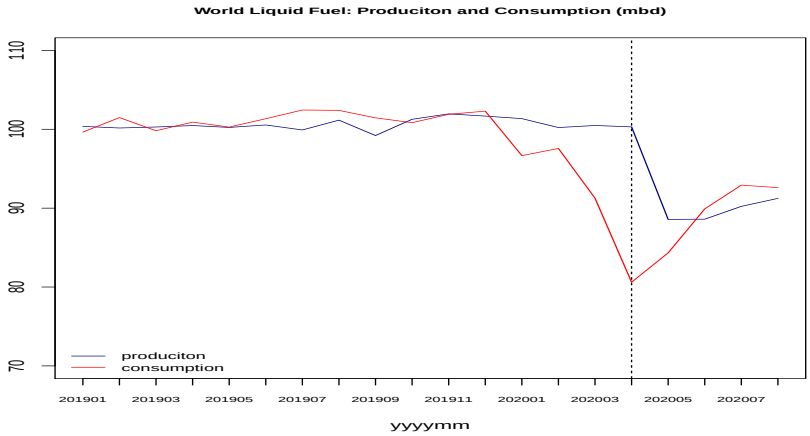


FIGURE 2.1. World liquid fuel production and consumption: monthly data, Jan 2019-Aug 2020. Note that on March 11, 2020, the WHO declared COVID-19 a pandemic. This is reflected in the drop in fuel consumption in March 2020. Data source: EIA

Year-Month	Motor Gas	Jet Fuel	Dist Fuel	Hydro	Total
201904	10.34	1.76	4.12	4.11	20.33
202001	9.67	1.67	4.00	4.57	19.91
202002	9.85	1.63	4.01	4.35	19.84
202003	8.53	1.39	3.91	4.45	18.28
202004	6.38	0.69	3.51	4.11	14.69
change from April 2019 (mbd)	-3.96	-1.07	-0.61	0	-5.64
change from April 2019 (%)	-38%	-61%	-15%	0%	-28%

TABLE 2.1. US petroleum consumption by each usage (mbd): April 2019 to May 2020. Data source: EIA.

Throughout the world, the dramatic plunge in demand for oil put huge downward pressure on the price of WTI. If the decrease in oil demand had been balanced by a supply cut, the price of oil would not have dropped as much. However, production remained at 100 mbd or even higher in March and until the end of April 2020. As a consequence, the excess production reached about 10 mbd in March and about 20 mbd in April, a historical high. In mid-April 2020, the major oil-producing countries (OPEC+) reached a consensus to cut production by 9.7 mbd starting in May, 2020. However, a supply cut is not easy to execute and take time: most oil-producing countries continued to keep production high for much of the month, exacerbating the glut situation.

On one hand, oil demand had dropped 20-30% throughout the world; on the other hand, oil supply reached a historical high. This situation of unprecedented oversupply created two issues: a surge in retail oil investors attracted by very low oil prices and a storage shortage. I discuss each issue in detail in the following sections.

2.2. **Retail investments surge.** Attracted by historically low oil prices and hoping for a rebound later, the number of retail investors and their investments in crude oil products

surged in March and April 2020. Most of these crude oil products were associated with WTI futures contracts. Because futures are highly leveraged, investments in such products usually require sophisticated knowledge and skill to be profitable. The flood of retail investors changed the mix of market participants.

In the US, the largest crude oil product in terms of asset under management (AUM) is the United States Oil Fund (USO), an ETF product with WTI contract futures as underlying assets. The USO product's AUM was $1.56 billion in early March and reached $4.3 billion on April 16, 2020, accounting for about 25% of all outstanding MAY contracts, the most-traded WTI crude futures then. The fund had record daily inflows of $552 million on April 17, bringing its total for that week to more than $1.6 billion. Moreover, many leveraged oil products attract aggressive retail investors. For example, ProShares' UCO, a product twice leveraged of daily oil prices, had a year-to-date inflow of $1.76 billion on April 17. Bouchouev (2020) presents detailed information on retail US products corresponding to the oil price change in early 2020.

This same picture prevailed all over the world. In China, many retail oil products are owned by big banks, such as China Industrial and Commerce Bank (CICB) and Bank of China (BOC). Most of these major state-owned banks have investment limits for their customers based on the foreign currency reserves they can use for investments at an aggregate level. However, BOC is an exception: BOC is the largest bank in China dealing with foreign currencies and does not have a limit on the amount of investment in its crude oil products. In March and April 2020, many retail investors reached their account investment limit and flocked to BOC for its product YuanYouBao (oil treasury) (Xinhua, 2020). The number of retail investors in YuanYouBao increased quickly from a few thousand in early 2020 to around sixty thousand by April 20, 2020.

Unlike experienced traders, most of these *new* retail investors lacked the basic knowledge and trading skills for WTI futures products and commodities market. For example, a survey of 120 YuanYouBao customers showed that 14% had never done any investments; among the rest, only 4% had basic knowledge of futures (SinaFinance, 2020). We discuss in details the connection of such a heterogenous market structure with trading activities of WTI contracts on April 20, 2020, in Section 4.

2.3. **Storage shortage.** The oil oversupply led to oil storage shortages worldwide in April 2020. In the US, pipelines, oil tanks, and oil refineries were all full of crude oil. This was illustrated vividly by tanker fleets standing by outside Los Angeles on April 23, 2020 (Fig. 2.2).

Cushing, OK, the delivery site for the NYMEX WTI futures contract, has the largest storage capacity in the US at 76 million barrels (Slav, 2020). However, on April 20, 2020, 60 million barrels' worth of storage was already in use, and traders had booked the remaining storage capacity. Thus, there was little storage space available for extra crude oil. Meanwhile, traders were holding thousands of contracts for crude oil delivery at Cushing on April 21. Table 2.2 shows that: by the fourth week of April, there was a stock of 63 million barrels (83% of the total storage capacity), a historical high with more than 50% of that in the fourth week of March. The supply glut continued into May, placing significant downward pressure on the price of WTI.

Year-Month	Week 1	Week 2	Week 3	Week 4	Week 5
2020-Jan	35,501	35,843	34,882	35,640	36,708
2020-Feb	38,376	38,243	39,149	37,178	NA
2020-Mar	37,882	38,445	39,303	42,824	NA
2020-Apr	49,241	54,965	59,741	**63,378**	NA
2020-May	65,446	62,444	56,857	53,462	51,723

TABLE 2.2. Weekly crude oil stock (thousands of barrels) at Cushing, OK from January 2020 to July 2020. Data source: EIA.

(A) Tanker fleet at port of LA

(B) Tanker fleet at port of LA

FIGURE 2.2. About 30 oil tankers stranded off the coast of Los Angeles on April 23, 2020. US Coast Guard video. Source: https://www.youtube.com/watch?v=rvKn5rN1f6k.

The storage shortage happened not only in the US. Early in March 2020, the crude oil storage was full in many other places. For example, South Korea's crude storage and products storage in Singapore had all been leased out by March, and the same thing happened in Europe.[5] In Canada, the storage shortage was even worse, especially for "landlocked" producers, such as those in Alberta's oil sands, who have limited access to global oil shipping routes. Western Canadian Select oil fell to -$0.01 per barrel on April 19, 2020 and -$4.68 the next day. Note that crude oil storage leases are long-term, typically lasting a year. Traders and dealers were looking for storage both on land and in the ocean. Reuters estimated that on April 17, 2020, there was a record 160 million barrels of oil held in floating storage on ships. US President Donald Trump even considered a ban on Saudi oil shipments to the US at that time. Given the dramatic decline in available storage space, storage costs increased by 50-100% in March 2020 and then skyrocketed in April 2020.[6] That is, if a trader had been able to secure a one-year lease for an 80,000-barrel tank at the LOOP, storage costs would have been about $528,000. Therefore, traders needed to take storage costs very seriously.

The May 2020 NYMEX WTI contract expired on April 21, 2020. Contracts held in a long position had to be sold before their expiration; otherwise, the contract holder would

[5]South Korea has the largest storage capacity in Asia.

[6]For example, CME Group's LOOP had its oil storage price spike from $0.07 per barrel in March to $0.55 in April 2020.

have to accept delivery. These contracts had either to be closed or roll over to the next period. Very few of them were for physical deliveries. Under normal conditions, the transactions would have been completed in the market with positive prices. However, on April 20, 2020, news spread that there was little space to store oil, and no one would risk buying oil (WTI futures contracts) with no place to store it! Thus, when delivery is not possible and there is no storage space, having oil can be a burden. To get rid of the burden, the contract holder has to pay someone else to take the asset! That is, the contract price can be negative! Indeed, the price of WTI fell into the negative in the afternoon of April 20, 2020. However, the May WTI contract settled at $10.11 the next day on April 21, 2020. Of course, the fundamental situation of oversupply and storage shortages did not change overnight. Therefore, there must have been other factors that caused the negative prices. I discuss how policy, trading rules, and trading activities contributed directly to the negative prices in the following sections.

3. Policy and trading rules

Under normal circumstances, the price of oil stays positive. Even in the extreme situation created by oversupply and storage shortages in April 2020, negative prices could not have happened without the necessary policy allowances and technical setup. In this section, I focus on the trading policy regarding trade-at-settlement (TAS) WTI contracts, CME's rule change allowing negative prices, and settlement pricing policy. These factors combined to make negative WTI prices possible.

3.1. **TAS: no netting limit with outrights.**

There are several types of contracts in the WTI futures market. One special type is called TAS.[7] TAS has been available for crude oil contracts since 2001.[8] TAS contracts are bought and sold at a price differential from the daily settlement price, so the final price of the TAS contract is the settlement price plus or minus a premium or discount. The TAS limits are +/- $0.10 for outright TAS and +/- $0.20 for spread TAS. Note that the trading hours for TAS are Sunday - Friday 6:00 p.m. - 2:30 p.m. ET. For market participants whose primary concern is exposure to the settlement price, TAS is an efficient means of executing transactions with no obligation to actually be in the market at close. Meanwhile, many speculators use TAS to generate profits.

In the WTI contract market, TAS positions can be netted *without limit* against other long or short positions in the same commodity contract. This unlimited ability to net TAS positions with outright positions presents opportunities for malfeasance or price distortions of WTI contracts: a market participant can establish a large open TAS position at the yet-to-be determined settlement price and then trade WTI futures contracts aggressively as an offset to affect the TAS settlement price in the trader's favor.[9] Research has found that TAS may create opportunities for profitable trade-based manipulation (see discussion in Section 1). Recognizing that improper use of TAS could result in market

[7]TAS contrasts with Trade-At-Marker (TAM), in which trades use the market price during the trading period.

[8]NYMEX Notice to Members No. 41, Jan 31, 2001.

[9]To limit such trading behavior in the WTI contracts market, the CFTC has brought enforcement actions arising from the use of TAS to manipulate prices in the WTI crude oil futures contract.

abuse and distortion, CME imposed limits on TAS trading in agricultural commodities in the most liquid contract months (usually the spot month). However, such a limit on TAS has not been implemented for the NYMEX WTI contract. On April 20, 2020, even the 2020 May WTI contract became inactive on that day, the May TAS contracts were traded in extraordinary amounts. The impacts of these TAS orders on the negative price event are discussed in detail in Section 4.2.

3.2. **Notice of negative price allowance by CME Group.** Before April 2020, zero and negative prices of NYMEX WTI contracts were not allowed by CME and those prices were not supported by the CME trading platform and clearing house.

On April 1, 2020, CME advised CFTC staff that CME was taking operational steps toward supporting negative pricing, as needed, for futures and strikes for options for certain energy products traded on CME's Globex, including the WTI contract.[10] CME then changed its computer system to allow for negative prices. On April 3 and 8, CME issued public notices and communications about the change to its members.[11] On April 13 and 15, CME announced to its clearing members that negative and zero prices of WTI contracts were ready to be implemented.[12]

On April 15, CME's clearinghouse stated that "recent market events have raised the possibility that certain NYMEX energy futures contracts could trade at negative or zero trade prices or be settled at negative or zero values, and that options on these futures contracts could be listed with negative or zero strike prices." CME also informed clearing members on the same day that "effective immediately, firms wishing to test such negative futures and/or strike prices in their systems may utilize CME's new released testing environments, for products CL (crude oil futures) and LO (options on those futures)."

Note that during pandemic, there was no rule change for other commodities to allow zero and negative futures prices.[13] Negative prices have occurred for natural gas and electricity in the spot and forward wholesale markets, but never in the futures markets. A related event in which a negative price nearly occurred in the futures market was the futures price of onion contracts in 1956: the price of onion contracts was 10 cents per sack of 50 pounds, making the actual price negative after subtracting the cost of the bag (20 cents).[14] When the price of WTI contracts fell into the negative on April 20, 2020, it was the first time in history that the price of a good went to negative in the futures markets.

[10]CFTC (2020), page 9-10.

[11]April 3, 2020, CME notice #20200403: https://www.cmegroup.com/notices/electronic-trading/2020/04/20200403.html; April 8, 2020, CME notice #20-152: https://www.cmegroup.com/content/dam/cmegroup/notices/clearing/2020/04/Chadv20-152.pdf

[12]April 13, 2020, CME notice #20200413: https://www.cmegroup.com/notices/electronic-trading/2020/04/20200413.html; April 15, 2020, CME notice # 20-160, https://www.cmegroup.com/notices/clearing/2020/04/Chadv20-160.html

[13]The WTI futures contract is the only one whose price fell into the negative during the pandemic.

[14]In history, the prices of natural gas and electricity have fallen into the negative due to oversupply and because they are byproducts or cannot be stored. The actual price of onions fell into the negative in 1956 due to price manipulation in the futures market.

3.3. **Settlement price of WTI contracts.** In 2020, the May WTI contract expired on April 21, so April 20 was the penultimate day for the May contract and the day the June contract became active.

For WTI contracts, CME sets the settlement period as 2:28:00 to 2:30:00 ET for all contracts except the expiration-day contract. On the last trading day, the expiring contract settles between 2:00:00 and 2:30:00 ET, based on the rationale that the expiring-day contract has less trading volume and the market is much less liquid than on other trading days. On each trading day, settlement price is calculated using a volume-weighted-average-price (VWAP) method. For active and expiration-day contracts, the VWAP applies to the outright CME Globex trades executed during the settlement period. For inactive months, the VWAP applies to accumulated calendar spread transactions during the settlement period, where the volume in each spread is divided by the number of months separating leg 1 and leg 2 of that spread.

Thus, April 20, 2020 is a very *special* day for the 2020-May contract in terms of settlement price construction. According to the CME rule, the settlement price for the May WTI contract on April 20, 2020 was based mainly on the calendar spread between the May and June contracts; the May-June spread widened from the previous trading day's closing spread of -$6.76 to -$58.06 per barrel on April 20, 2020. The last two minutes from 2:28:00 p.m. to 2:30:00 p.m. ET were used to calculate the settlement price for the May contract, which was -$37.65.[15] Thus, we see that the prices during the last two minutes were critical to the settlement price of the WTI contract on April 20, 2020.

4. Trading activities on April 20, 2020

The extreme situation in April 2020, such as the oil glut and storage shortages, created an environment conducive to low oil prices but did not necessarily have to lead to a negative price. In early-mid April, CME changed its rules to allow negative prices for WTI contracts starting on April 16, 2020. This rule change made negative prices possible, but it did not cause the price of oil to fall into the negative per se. So, what really happened on April 20, 2020? In the following, I present information about trading activities on April 20 and argue that market illiquidity and heterogeneous investors contributed to the negative price.[16] I discuss the following factors in this section:

- Illiquidity issues resulting in very inefficient price discovery.
- Extremely large number of TAS orders resulting in potential price distortion.
- Bank of China's large long TAS positions were not closed early, providing an opportunity for speculators.
- Speculation trading potentially leading to price impacts.

4.1. **Illiquid market.** Fig. 4.1 shows daily trading volume and prior-business-day open interest for each WTI contract month: March (H), April (J), May (K), June (M), July (N), and August (Q). The data are from January 22 to July 21, 2020, with expiration dates of February 20, March 20, April 21, May 19, June 22, and July 21 for these contracts. In the plot, the label K indicates the contract for May 2020, which traded between March

[15]This was a case of contango because the June contract had a higher price than the May contract.

[16]The negative price occurred in a 20-minute period between 2:08 p.m. and 2:30 p.m. ET

21 and April 21, 2020. The April 20 data in both plots are in red. April 20's trading volume and open interest were comparable with other penultimate days.

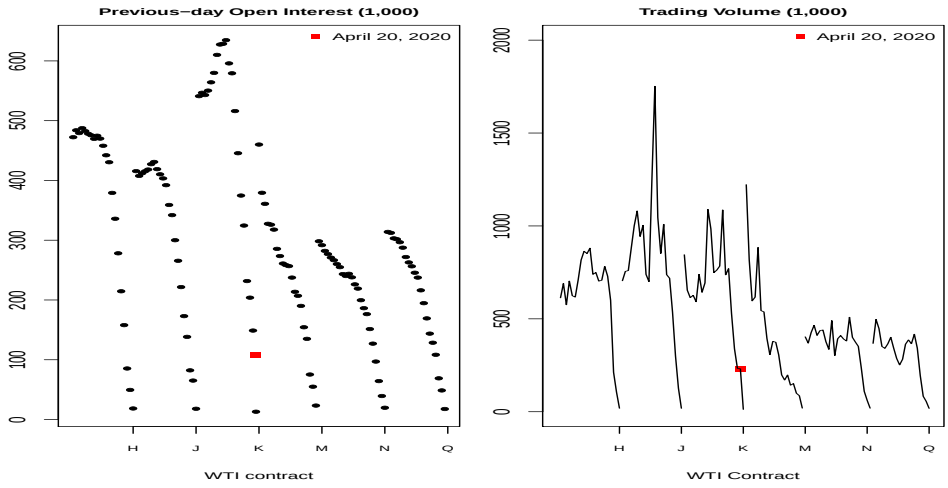


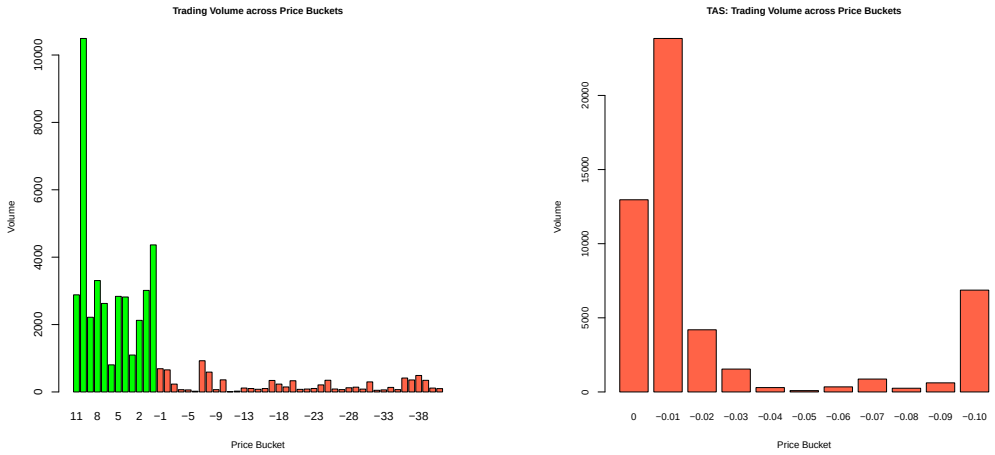
FIGURE 4.1. Trading volume (right plot) and prior-business-day open interest (left plot) for each WTI contract: March (H), April (J), May (K), June (M), July (N), and August (Q) in 2020. Data source: EIA, Bloomberg, CME group.

I now turn to the trading volume of outrights on April 20 from 9 a.m. to 4 p.m. ET. The left plot in Fig. 4.2 shows the trading volume for each price bucket (one USD) from \$11 to -\$41. Since the price was dropping on April 20, this is also the distribution of trading volume over time. On April 20, 2020, a negative price occurred with very thin transactions, only about 18% of the total daily trading volume. This implies that the negative price resulted from residual trading activities.

Another metric for liquidity is the tick price (discount or premium of the settlement price) of the TAS contracts. The right plot in Fig 4.2 shows the trading volume of TAS outrights for each tick. First, the ticks are all negative, indicating a significant asymmetry: more sellers than buyers in the TAS market. Second, there was a large trading volume around the level of the maximum negative ten ticks on April 20, indicating the depth of the illiquid TAS market. Usually, the TAS discount/premium prices are around one or two ticks from zero; ten ticks is extremely rare.

The U-shaped trading volume distribution in the right plot of Fig.4.2 indicates that TAS trading was active earlier in the morning, around 10-12 a.m. ET, decreased around 12-2 p.m., and then increased dramatically around 2-2:30 p.m. While we cannot draw the conclusion that traders manipulated the price during 2-2:30 p.m., it is fair to say that the selling pressure would have put significant downward pressure on the price during this period. From an economic perspective, traders who bought TAS contracts earlier in the day had an incentive to lower the settlement price in the last moments of the trading session.

4.2. **Large amount of TAS orders.** There was an unprecedented large number of TAS contracts on April 20, 2020 (Table 4.1). The total trading volume of TAS was 77,076 contracts (77 million barrels of oil). Of those, 51,867 were outright TAS, and 25,209 were



(A) Volume for Price Bucket (B) Volume for TAS Tick

FIGURE 4.2. Trading volume by price buckets (left plot) and TAS tick prices (right plot) Left plot: green bars represent positive prices and red bars represent negative prices. Data source: Bloomberg.

spread TAS. Note that outright TAS was the single largest source of trading volume on April 20 (almost 21%). Why was there such a large number of TAS orders in the WTI contract market for the May contract? This was related to the large increase in retail oil products. Many of these investment products (such as, BOC's YuanYouBao) seek to achieve the settlement price.

Contract Type	Buy Volume	Sell Volume	% of Total
Outright regular	45,292	45,292	18.3
Outright implied	13,401	46,093	12.1
Spread regular	49,056	49,056	19.8
Spread implied	46,303	13,611	12.1
Outright TAS	51,867	51,867	20.9
Spread TAS	25,209	25,209	10.2
Exchange for physical	11,300	11,300	4.6
Other trades	5,519	5,519	2.1
Total	247,947	247,947	100

TABLE 4.1. Trading volumes by contract type on April 20, 2020. Data source: CFTC Interim Staff Report, November 23, 2020.

During the April 20 trading session, of the total number of 51,867 outright TAS contracts, 11,658 were traded at the maximum limit. This was 22% of the total daily volume of outright TAS and was more than 70 times higher than in all of 2019 (Table 4.2). How did these extreme TAS trading activities affect the price of WTI crude oil futures? Pirrong (2019) investigates a TAS manipulation model and finds that the TAS orders generate

profits if information is asymmetric and the impacts on prices are larger when the market is not liquid. This study also finds that selling has greater impacts than buying. Both informed traders and large numbers of inexperienced retail investors participated in the WTI futures market, which was very illiquid on April 20, 2020. Hence, the conditions of information asymmetry and market illiquidity were both met on April 20, 2020. In the afternoon of that day, with trading volumes thin and sellers outnumbering buyers, the TAS contracts quickly moved to the maximum allowable discount of ten cents per barrel. For a period of about an hour, from 1:12 p.m. until 2:17 p.m. ET, trading in these contracts all but dried up. There were no buyers. If TAS holders were dumping or hedging by selling outright contracts, this would have pushed the price down much further given that buyers were thin. At 2:08 p.m. ET, WTI turned negative. Twenty minutes later, it sank as low as $-40.32 before rebounding slightly at the close.

Date / Period	Trade Count	Volume	April 20 / Volume
All 2019	49	164	71
Jan 31- Apr 17, 2020	264	941	12
April 20th, 2020	1,101	11,568	1
Apr 21 - May 31, 2020	412	851	14

TABLE 4.2. Trading activity: number of outright TAS trades executed at the maximum differentials. Data source: CFTC Interim Staff Report, Nov 23, 2020.

Based on the TAS positions only, I estimate that the maximum loss/gain of the market was between $570 million and $1.15 billion (Table 4.3). Because this is a zero-sum game, some participants' losses are others' gains. According to public information, Bank of China incurred a large loss (the exact number has not been disclosed) while Vega Capital made a huge profit of about $500 million.[17] I focus on major market participants in the following sections.

Market	Before 2pm	After 2pm	Total
contracts	48,871	2,996	51,867
max (20,57), milloin	977	171	1,148
min (10, 28.5), million	489	85	574

TABLE 4.3. Market loss/gain: number of outright TAS contracts traded for the full day, before and after 2 p.m. ET. Data source: CFTC Interim Staff Report, Nov 23, 2020.

4.3. **Bank of China: YuanYouBao.** In a liquid market, TAS trades are fairly balanced between sellers and buyers. the May 2020 contract, however, was an exception. While most big TAS players' long positions had closed before April 20, 2020 or earlier in the day, BOC, one of the biggest participants, kept its TAS long positions in the market until

[17]See details in Vaughan et al. (2020). Interactive Broker incurred a loss of $104 million due to that the platform was not designed to handle negative oil prices.

it was forced to close due to the settlement price being negative, and incurred a massive loss.[18]

In January 2018, Bank of China launched a restructured WTI contract product, YuanYouBao (crude oil treasury), to retail investors.[19] In early 2020, BOC marketed its product, YuanYouBao, very aggressively, saying that "oil is cheaper than water, come to trade with Bank of China!" (Fig. 4.3). The number of YuanYouBao customers increased from about 4,000 in early 2020 to about 60,000 in April 2020 (Table 4.4). Many of these retail investors had no investment experience with derivatives.

FIGURE 4.3. An advertisement for YuanYouBao: "Crude oil is cheaper than water, come to trade with Bank of China!'

Investment Amount (RMB)	Number of Retail Investors
<10,000	20,000
10,000 - 50,000	20,000
>50,000	20,000

TABLE 4.4. YuanYouBao of Bank of China: Customer distribution by investment amount (RMB). Source: CaiXin.

In total, YuanYouBao customers held about 24,000 long positions of WTI TAS contracts on April 20, 2020.[20] On average, each customer invested in 400 barrels of WTI. According to a statement by Bank of China on April 24, 2020, about 46% of customers closed their positions before 10am ET, while the rest (the majority of which was long and only some short) stayed in the market.[21] Note that the market price at 10 a.m. ET was $11.70. If we assume 12,000 contracts in the long positions that were not closed before 10 a.m. ET, this was about 15% of the total TAS positions in the market on April 20, 2020. My loss estimate for YuanYouBao is between $200 and $680 million, with the minimum loss of $80 million resulting directly from the negative prices.

[18]Rollover timeline of big TAS players on 2020 May contract: April 8-14: USO; April 14-15: CIBC and CCB; April 20: BOC, YuanYouBao.

[19]The product divided each contract of 1,000 barrels into 1,000 units, so that a retail customer could buy one barrel. Bank of China charged 2% for each rollover.

[20]https://www.weiyangx.com/357313.html

[21]https://www.boc.cn/custserv/bi2/202004/t20200424.html.

Note that YuanYouBao was designed to roll over on the day before expiration. Retail investors can conduct transactions only before 12 a.m. (Beijing time, midnight), which is 10 a.m. ET in US. One relevant question here is, why did YuanYouBao allow investors to remain in the market right up to the penultimate day of the contract, thereby exposing them to high levels of volatility and potential risk? This was due to the product design, which allowed customers to roll over on the penultimate day, but not before and did not allow them to place orders after 10 a.m. ET (12 a.m. Beijing time). Therefore, investors could not close their long positions between 10 a.m. ET and 2:30 p.m. ET on the penultimate day.[22] Note that these trading rules and large positions of TAS orders of BOC were public information.[23]

4.4. **Speculation activity.** Regarding the role of speculation, I provide here a hypothetical example of possible "profits from TAS" on April 20, 2020. A trader figures that during the penultimate day, many people will want to get out of their positions, but there will not be many buyers, and the market will not be liquid. This information is private to the trader. The trader purchases 3,000 TAS WTI contracts early on April 20. Later in the day, the trader sells 1,000 outrights at $10. There are not many buyers in the market, so she sells another 1,000 outrights at -$5, then makes a final trade for 1,000 outrights at -$25 close to 2:30pm ET. The dollar amount the trader will *receive* for the sale transactions is

$$1,000 \times (10 - 5 - 25) \times 1,000 = -\$20\ million,$$

which means that the trader will pay out $20 million in total for the sale of 3,000 outrights. However, the trader "bought" TAS, which is settled at the settlement price – the volume-weighted average price from 2:28 to 2:30pm ET - which ends up at -$37.65. The dollar amount the trader will *pay* for the purchase transaction is

$$3,000 \times (-37.65) \times 1,000 = -112.95\ million.$$

That is, the trader receives $112.95 million for the TAS contracts. Thus, at the end, the trader has her 3,000 TAS long positions offset by the 3,000 outright short positions and walks away with a profit of $92.95 million. There is nothing wrong with taking an opportunity to profit. However, price manipulation is not allowed by law. The unintended impact on price can be huge when the market is not liquid, which poses a challenge for differentiating hedging and manipulation. Note that traders can work together, and their joint impacts on price can be even larger.

There was such intense speculation activities involving TAS orders on April 20, 2020, that as Bank of China and others were selling May contracts, experienced traders were buying them up in the TAS market. As the settlement time approached, these traders aggressively sold outright WTI contracts and other related instruments, contributing to the downward pressure on the price. Note that sellers pushed the TAS discount out until it reached its maximum daily limit of 10 cents soon after 2 p.m. ET. Reaching this limit

[22]We do not know if these positions can be handled by the Bank of China traders between 10 a.m. ET and 2:30 p.m. ET. The Bank of China cannot trade on behalf of its customers, however, BOC may establish positions of their own and trade those positions either directly or through an agent in the WTI futures market.

[23]I thank the referee who raised a question wether these rules were known by other investors.

of ten cents was unprecedented for TAS, which ordinarily trades at a maximum of 1 or 2 cents above or below settlement. The negative price occurred around 2 p.m. and lasted to 8 p.m. ET on April 20, 2020 for about 6 hours.[24]

It should be addressed that once the price fell into the negative, irrationality and fear exacerbated the situation, another factor that drove the negative price spiral. Responding to fundamental economic factors, investors overreacted to the negative price event out of fear to such an extent that they detached economic fundamentals from prices. This also partly explains why under the same fundamental conditions, the price rose into the positive again on April 21, 2020.[25]

In sum, it seems that speculators took the opposite of retail investors' positions in TAS orders in an illiquid market with significantly flawed oil products (YuanYouBao) and a rule change by CME allowing negative prices. The futures market, fundamentally speaking, should be an efficient price discovery system for physical users, investors, and speculators; not a means of price distortion. On the other hand, no market or trading system is perfect. The fundamental questions are: What is the proper role of the futures market? Should negative prices be allowed in the future for crude oil?

5. What can we learn?

WTI is the most traded derivative in the commodity world. Needless to say, the impact of a negative oil price is huge and long-lasting. To minimize manipulation, improve market efficiency, and make the market fair for participants, I propose the following policy enhancements and rule changes.

(1) More advance notice of structural market changes.
(2) Settlement pricing with robustness to outliers and contextual market situation.
(3) Appropriate limits and application conditions for TAS contracts.

The order is not in terms of importance, and these measures should be considered jointly.

5.1. **Length of notice for any structural change.**

The policy of allowing negative prices and the technology setup for trading at negative prices constitute a structural change to the WTI contract market. The chart below shows the timeline of the change made by CME.

April 1 :	*advised CFTC about negative prices*
April 3 :	*changed computer code*
April 8 :	*informed clearing members that zero and negative prices were possible*
April 13 :	*informed clearing members that testing was complete*
April 15 :	*asked clearing members to transact with negative prices*

Only twenty days passed between announcing the change and the negative price event on April 20, 2020. Should more advance notice of such structural changes be given for the benefit of investors and the efficiency of the derivatives market? I argue that regulators need to set a rule on the length of notice required before any structural change is implemented in the market. Also, providing time for the public to give feedback about

[24]Bloomberg BusinessWeek reported that Vega Capital London Ltd., an energy trading company in London, pocketed as much as $500 million on April 20, 2020.

[25]The irrationality factor is suggested by a referee.

any such changes would benefit the market. For example, regulators could require a three-month public hearing period. This would give investors enough time to familiarize themselves with any proposed changes. Otherwise, such changes will create unfairness by benefiting more seasoned investors (usually speculators) and putting retail investors at a disadvantage.

5.2. **Settlement price: proper construction.** I propose three changes to improve settlement pricing: extend the settlement period on the penultimate day, use the median instead of the mean, and add a condition of market liquidity to the formula. I discuss each proposal in detail below.

Longer settlement period In general, the last two minutes' prices do not represent the real market price of the trading day. This is especially true when the trading volume is very low during the last two minutes, which is very common around contract expiration dates. Trading ahead of expiration tends to get thinner as traders exit their positions, leaving prices more vulnerable to influence. For example, on April 20, 2020, there were only about 500 contracts in the last two minutes of transactions, in contrast with the total trading volume of 240,000 for the day. I propose a longer settlement period around expiration days, such as extending the thirty-minute settlement period from only the last trading day to the last two trading days. That is, on April 20, 2020, the settlement price would have been calculated based on the prices of the last thirty minutes rather than the last two minutes. This would reduce the opportunity for market participants to manipulate prices.

Volume-weighted median price I propose an alternative to the price weighting methodology. There are caveats associated with VWAP including that it is not robust to outliers. Let P_S be the settlement price during the settlement period $s \in S$. At time s, P_s is associated with trading volume V_s. We have

$$P_S = \sum_s w_s \times P_s, \qquad \textit{where } w_s = V_s / \sum_s V_s.$$

Clearly, the weighted sum is not robust to outliers, which can be associated with either a large volume trade (concentrated among a few participants) or a small volume trade. One way to overcome this is to use the median.

A combination, such as a volume weighted median price (VWMP) in the last ten minutes or thirty minutes, makes more sense than using the average price for the last two minutes. Fig 5.1 shows settlement prices over different time horizons of three minutes, thirty minutes, and the full day on April 20, 2020. The left plot is for VWAP, and the right plot is for VWMP. First, across different time periods, for both the average and median methods, settlement price increases dramatically when the construction period changes from three to thirty minutes and then to a full day. Second, the median method yields settlement prices from -$17 to -$1.8 and is therefore more robust to outliers than the average method.

Conditional volume-weighted price There is a serious drawback of using a linear volume weighted price: it cannot reflect whether the market is liquid. In other words, because volume-weight is relative to the total volume in a given period, the low-volume and high-volume scenarios could result in the same settlement price.

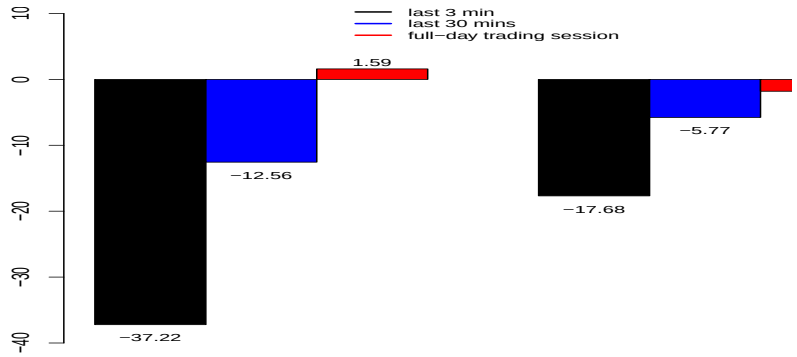


FIGURE 5.1. Volume-weighted settlement price: Average (left plot) and median (right plot) on April 20, 2020.

A low trade volume indicates that the market is illiquid, meaning there is a higher chance the price of WTI could be distorted and to a large degree. If we add conditional volume information to the price, the low-volume prices will be discounted, and large-volume prices will receive more weight, reflecting the market's efficiency. To illustrate this, assume three transactions occurred at 2:28, 2:29 and 2:30 ET(Table 5.1). There are two possible cases: high trading volume and low trading volume. Scenario 1 assumes the prices are the same for both cases. Regardless of differences in market liquidity, the settlement price for the two cases is the same: $\frac{P_1+2P_2+3P_3}{6}$. In reality, sophisticated traders would realize the market is not liquid and could take advantage of the situation to manipulate the price. Assume the price stays the same for the liquid market but doubles for the illiquid market in Scenario 2. The settlement price for the illiquid market is $\frac{P_1+2P_2+3P_3}{3}$, and double that for the liquid market! Here, the volume-weighting scheme does not have much meaning. Therefore, I propose adding a condition of market liquidity to the price calculation. This can be called the conditional volume-weighted average price (CVWAP).[26]

	s=1	s=2	s=3
Scenario 1			
Liquid market: volume	100	200	300
Illiquid market: volume	10	20	30
Price	P_1	P_2	P_3
Scenario 2			
Illiquid market: volume	10	20	30
Illiquid market: price	$2P_1$	$2P_2$	$2P_3$

TABLE 5.1. Limitations of simple volume-weighted average pricing.

[26]Note that CME adopts bid/ask spread as a substitute for the volume weighted price when trading activity is low. However, the detailed algorithms are unknown.

5.3. **Impose TAS limits.** Currently, there is no limit on TAS contracts for the WTI market. Recall that TAS was originally designed for the most liquid products. Thus, very low liquidity violates the conditions for TAS to be valid. To show the rationale for TAS limits, let's consider the following equation simulating profits generated from transactions by a speculator with N contracts.

$$Profit = \sum_{t \in T} N_t P_t - N P_S \tag{5.1}$$

where N_t is the trading amount of outrights at time $t \in T$, T is the daily trading period, and P_S is the settlement price. Before the market closes, all TAS positions are netted with outrights, $N = \sum N_t$. Assuming the market is efficient and there is no price manipulation, the profit should be a random variable around zero. However, when the market is not liquid, a market participant with a large N could impact the price. A series of transactions in the same direction (buy or sell) would put high pressure, upward or downward, on the price of a contract. From a concentration perspective, the shorter the settlement period, the larger N can be. For illustration purposes, I discuss the impacts of S and N on settlement price separately.

Consider settlement period first. Let S denote the period for the settlement price. For the sake of simplicity, I omit the volume. Denoting $G(\cdot)$ as the profit function and defining $\bar{N}_s = \frac{N}{S}$, we have

$$G(\cdot) = \sum_{t \in T} N_t P_t - \sum_{s \in S} \bar{N}_s P_S = \sum_{t \in T} N_t P_t - \sum_{s \in S} \bar{N}_s \times \mathrm{E}(P_s). \tag{5.2}$$

Since $S \leq T$, we know that $P_s \subseteq P_t$, hence (5.2) has the following implications:
(i) $S \to T$, $P_s \to P_t$, $G(\cdot) \to 0$.
(ii) If P_s and P_t have the same sample distribution, then $G(\cdot) = 0$. For example, the trading during S is representative of trading during T.

Now lets consider the impacts of N which may impact both P_t and P_S, particularly in an illiquid market. Let $\bar{N}_t = \frac{N}{T}$, we can rewrite (5.2) as follows:

$$G(\cdot) = \bar{N}_t \sum_t \left(P_t(N_t, N_{t-m}) - P_S(N)\right) \tag{5.3}$$

$$P_S(N) = \int_{T-S}^{T} v_s p_s(N) ds \tag{5.4}$$

where v_s is the weight and p_s is the price density during the settlement period S. The impact of N on $G(\cdot)$ is through two channels: direct as a multiplier and indirect through its impacts on prices. The latter is usually nonlinear.

Based on the analysis above, I propose the following changes to limit potential gains generated from price distortion associated with TAS orders.

• *Limit the size of N* Imposing a size limit could reduce the chances for price manipulation. Because market participants have different needs, a one-size-fits-all approach may not work. I propose different sizes for different types of entities, e.g., N=10,000 for asset management companies and N=1,000 for individual investors.

• *P_S representative of the market* The longer the settlement period, the less chance of distortion in the settlement price. Extending the settlement period is one option. Another way is

to impose application conditions for TAS. In principle, TAS makes sense only when the market is liquid and efficient. In practice, the application conditions can include market liquidity.

The above are just a few proposals to enhance market efficiency and fairness. Given the size, impacts, and importance of the WTI market, more studies need to be done along these lines. An efficient and fair oil market will benefit and protect all market participants.

6. CONCLUSION

The price of WTI fell into the negative on April 20, 2020. This is the only time in history that the price of oil has fallen into the negative. The intent of this paper is to: (1) explain what really happened around April 20, 2020 that caused the price of oil to fall into the negative. (2) offer proposals based on lessons from the negative price event that can enhance the efficiency and fairness of the WTI derivative market. (3) stimulate reflection on fundamental questions regarding the prices of goods.

I first investigate the negative price event and attribute it to factors belonging to three categories. The first category is macro-level fundamentals. The COVID-19 pandemic caused a dramatic plunge in demand for oil starting in March 2020 and reaching its lowest level in April. Meanwhile, the oil supply increased in April due to the price war between Russia and Saudi Arabia, resulting in low prices of WTI and storage shortages. These macro-level fundamental factors drove the price of oil to a historical low, but not necessarily into the negative. Retail investors flocked to the market hoping that the price of oil would rebound later. The second category is rule changes for policy enhancement: CME Group announced in early April that negative prices would be allowed and then on April 15 that the system was ready to accept negative prices. TAS can be used by sophisticated investors for price impact in an illiquid market. The third category is the trading activities on April 20, 2020. The 2020 May contract expired on April, 21, 2020, so on April 20, market was less liquid than on previous days. Some big players, such as Bank of China, had a large number of retail investors with long positions of TAS contracts. After 10 a.m. ET, there were more sellers than buyers in the market. Meanwhile, sophisticated speculators contributed to the price dropping into the negative after 2 p.m. ET. In sum, it was the joint effects of all of these factors that caused the negative price.

The original function of the derivatives market is to serve as an efficient price discovery system for physical products delivered in the future. In this study, I offer three proposals to improve market efficiency and fairness: (1) Provide more advance notice of trading rule and structural changes. (2) Calculate settlement prices to be more robust to outliers and conditional on market liquidity. (3) Impose limits on TAS contracts, which would help to minimize price distortion from speculation.

There are fundamental questions raised in this paper but is not yet answered: Do negative prices make sense? Should we allow negative prices in the first place? These require further study by both academia, market product owners, market participants, and regulatory agencies.

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